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INSECTS INJURIOUS TO THE VINE IN CALIFORNIA.

Phylloxera (*Phylloxera vastatrix* Plan.).
Grape Leaf Hopper (*Typhlocyba comes* Say).
Imported Grape Root Worm (*Adoxus vitis* Fourcroy).
Hawk Moth Larvæ.
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By H. J. QUAYLE.

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INSECTS INJURIOUS TO THE VINE IN CALIFORNIA.

By H. J. QUAYLE.

California, with its extensive areas of vineyards and lack of extremes in climate, offers suitable conditions for the development of a considerable number of insect pests of the vine. Here also the large plantings of the European, or vinifera, vines have given the phylloxera an opportunity to do greater damage than elsewhere in the United States.

Of the two hundred and seventy-five insects we have recently listed as attacking the vine throughout the world, only a very few (a dozen or two) are really of any economic importance; all the others being, generally, but casual visitants. Two or three of these of economic importance attack the roots, while the remainder feed upon the parts of the plant above ground.

The roots are sapped of their juices, rendered knotty, and caused to decay by the phylloxera. Strips or rings of the bark are eaten out by the root worm, and the fibrous roots are devoured by wire worms. The juices of the leaves are sucked out by the vine hoppers, irregular holes eaten away by flea beetles and leaf chafers, or chain-like strips by the root beetles; the edges rolled by the leaf-roller, or the foliage devoured completely by hawk moth larvæ, grasshoppers, cut worms and army worms. The young buds are destroyed by the flea beetle and by cut worms; and the shoots, petioles, pedicels, and berries have chain-like furrows gouged out by the root beetle.

With the possible exception of the root beetle, all the insects attacking the vines in this State are native American insects. The present bulletin is intended to give simply a popular account of the more important of these. More or less extended studies have been carried on during the past year on the vine hopper and root beetle, and these will be treated of in separate bulletins and only summary accounts given here.

PHYLLOXERA.*

(*Phylloxera vastatrix* Planchon.)

Historical.—The phylloxera is a native of the United States east of the Rocky Mountains, where it is found living upon the wild vines. It is a minute insect, related to the scale insects and plant lice.

The insect was probably introduced into California upon vines, cuttings or roots, imported from France, though it was possibly introduced

* Revised from Bulletin No. 131, by F. T. Bioletti.

from several sources and at several points. It was first noticed in the southern part of Sonoma County, in the valley surrounding the old town of Sonoma, about 1874. By 1880 vines killed by the insect had been found in Napa, Solano, and Placer counties, and hundreds of acres had been pulled up in Sonoma Valley. Since then the insect has spread to all the important grape-growing regions of California north of Tehachapi*, and probably not less than fifty thousand acres have been destroyed.

The Insect.—The phylloxera occurs normally in four forms, which have been called by Victor Mayet:

1. The gall insect, or form of multiplication;
2. The root insect, or form of devastation;
3. The winged insect, or form of colonization;
4. The sexual insect, or form of regeneration.

The gall insect lives upon the leaves, and is the commonest form on the wild vines in the native habitat of the insect. It rarely or never occurs in California. In Europe it is found often upon American and rarely upon European varieties. It causes little swellings or galls upon the leaves and younger parts of the vine, which, though sometimes very numerous, do little permanent injury. The chief danger from the gall form is that it multiplies with astonishing rapidity and migrates from the leaves to the soil. Here it attacks the roots and gives rise to the root form, which is the "form of devastation," the one which finally destroys all the vines it attacks which are "non-resistant." Every insect of the root form which reaches maturity lays about twenty-five or thirty eggs, each of which is capable of developing into a new egg-layer *needing no fertilization*. As there are from five to seven such generations during the year the increase in numbers is extremely rapid.

FIG. 1. Under side of grape leaf showing galls caused by Phylloxera. This form seldom, if ever, occurs in California.

Sometimes during the summer, usually in July or August, some of the eggs laid by the root insects may develop into insects of slightly different form, called nymphs. They are somewhat larger than the

* The phylloxera is said to have been found once in Southern California, but as the vineyard was uprooted and destroyed the insect was probably extirpated.

normal root form and show slight protuberances on the sides, which finally develop into wings. These are the winged or colonizing insects, which emerge from the soil, and, though possessing very weak powers of flight, are capable of sailing a short distance, and if a wind is blowing may be taken many rods, or even miles. Those which reach a vine crawl to the under side of a leaf and deposit from three to six eggs. These eggs are of two sizes, the smaller of which produce males and the larger females. The females arising from these eggs, after fertilization, migrate to the rough bark of the two-year-old wood, where each deposits a single egg, called the winter egg, which remains upon the vine until the following spring. The insect which hatches from this egg in the spring goes either to the young leaves and becomes a gall-maker, or descends to the roots and gives rise to a new generation of egg-laying root-feeders.

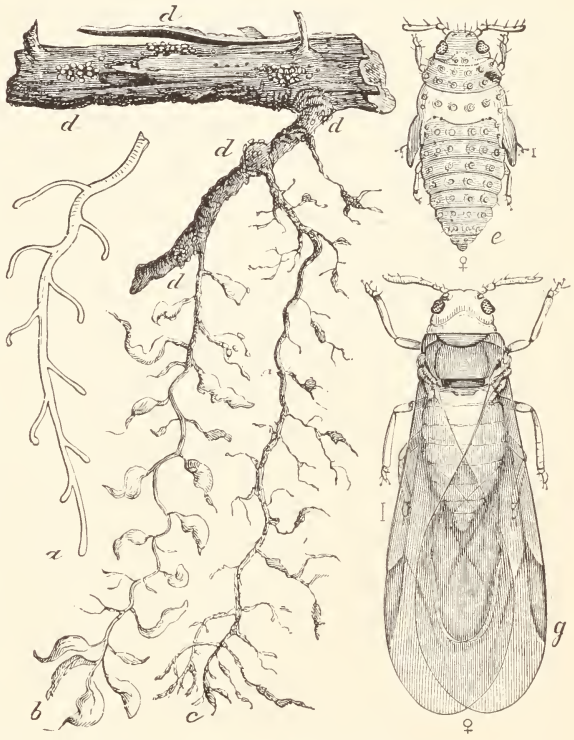

FIG. 2 Root-Form of Phylloxera. *a*, healthy root; *b*, root on which the lice are working, representing the knots and swellings caused by their punctures; *c*, root deserted by lice and beginning to decay; *d*, *d*, *d*, show how the lice appear on the larger roots; *e*, the nymph; *g*, winged female. After Riley.

The normal and complete life cycle of the phylloxera appears then to be as follows: *Male* and *female insects* (one generation in autumn); *gall insects* (one to five generations while the vines are in leaf); *root insects* (an unknown number of generations throughout the year); *nymphs*, which become *winged insects* (one generation in midsummer). The gall stage may be omitted, as it generally is in California, and the insects which hatch from the fertilized eggs laid by the female go directly to the root and produce offspring, which are indistinguishable from the root form produced in the normal cycle. For how many generations the root form can exist and reproduce without invigoration supposed to come from the production of the sexual form is not known, but certainly for four years and probably more. The gall form on

American vines may probably be prevented by spraying the vines in winter to kill the winter eggs; but this treatment has no effect on the root forms, which in California hibernate abundantly in the soil.

All forms of the phylloxera are extremely minute, the root form being about one twenty-fifth of an inch long when it reaches the adult egg-laying stage, and little more than half this length when young and active. It is just large enough to be seen by the unaided eye in a good light when its presence is known, and, by the help of a glass magnifying five diameters, its legs and antennæ are plainly visible. Its color is light greenish-yellow in summer, and somewhat darker in winter; so that when numerous the attacked roots appear as though dusted in spots with powdered mustard or cinnamon. The newly hatched insect is fairly active, and at first moves about from place to place on the roots, but finally, when it reaches the egg-laying stage, inserts its sucking-tube into the root and remains fixed.

Nature of Injury.—The amount of nutriment taken from the vine by such minute insects, even when present in the immense numbers in which they sometimes occur, is not sufficient to account for the disastrous effect upon the plant. The death of the vine is due to the decay which sets in wherever the phylloxera inserts its sucking-tube, for a swelling is produced, composed of soft tissue, which soon decays. When this swelling occurs at the end of a young rootlet, growth in length is stopped; when it occurs on larger roots, a kind of "cancer" or decay spot is finally formed, which soon extends around the root, and all below the point of attack dies.

During the first year or two after a vine is attacked there is little apparent damage. In fact, the effect of the phylloxera is equivalent to root pruning, and in some cases results in an unusually large crop of grapes. The year after this crop, however, the vine having endured the double strain of heavy bearing and root injury, is unable to recuperate, and generally dies. In rich moist soil the death of the vine is not so sudden, and two or even more crops may mature after symptoms of the disease are evident.

Methods of Dispersal.—The ways in which new vines and vineyards become infested may be classed as natural and artificial. The natural ways may be inferred from what has been said of the life history of the insect. From a vine first attacked the root form spreads through the soil to neighboring vines slowly, but continuously, thus forming the so-called "oil-spots." A typical oil-spot of several years' standing will show several dead vines in the center, then a ring of vines with very short growth and no grapes, next another ring where the growth is not of normal vigor, but where the crop may be equal to or larger

than that of the healthy vines. Such a spot enlarges its area year after year at a gradually accelerating rate as the front of the invading army becomes longer. The rate of advance will vary with the soil and climate, but will probably never exceed forty or fifty feet annually. If this were its only method of spreading, the insect could be controlled or even exterminated with comparative ease. Unfortunately, it is able to spread much more rapidly by means of the winged form; and the rapidity of its extension over the south of France was due principally to this agency. In California, though the winged form has been found, it seems to be rare, especially in the central valleys, which probably accounts for the comparative slowness with which new districts have become infested. The artificial methods of dispersal here are probably more effectual in spreading the insect than the natural. The insects are taken from one part of the vineyard to another on pieces of the roots of infested vines adhering to the plows or other implements used in cultivation; while they are introduced into new localities on rooted vines or cuttings brought from infested districts.

METHODS OF COMBATING THE PHYLLOXERA.

The methods to be used in resisting this foe of the vineyardist may be divided into groups corresponding to different stages of infestation and to varying local conditions. There are three cases to be distinguished, viz: 1. When the district is uninfested; 2. When a few small infested spots are known in the district; 3. When the district is badly infested; *i. e.,* shows many and widely distributed infested spots, even though none of the spots are large.

1. In the first case, all efforts should be directed to keeping out the pest, and the only effectual means is a rigidly enforced embargo on all material capable of introducing it. Although the phylloxera, so far as known, feeds on nothing but the vine, there is always danger of eggs or insects being contained in the earth attached to any kind of root. This measure, consistently carried out, has kept the province of Algiers free from infestation, though the neighboring province of Constantine has been a prey to the pest for many years.

2. In the second case, where the insect has already obtained a foothold, the first step to take is to determine as nearly as possible the exact extent of the infested area. If it is found to be confined to a small, isolated vineyard, an effort should be made to completely eradicate the pest. This can be done only by destroying the vineyard, by subjecting it to what is called the "death treatment." This is best done (after grubbing up the vines and burning them on the ground) by making an embankment around the whole vineyard and then running water on to it until it is converted into a lake. The water

should be kept continuously at a depth of at least six inches until all the insects are destroyed. The best time to do this is in May or June, as at that time four weeks of continuous flooding is sufficient to kill both insects and roots. It is important that every root should be killed in order that, if any insect survives the flooding, it will die for lack of food. Where flooding is impracticable, the vines should be grubbed out and burned in the same way, and the ground kept clean of all growth for at least one year. This is in order that any suckers which may come up from the roots may be destroyed immediately. If crops, or even weeds, are allowed to grow, some of these suckers may escape observation and keep the insects alive to spread the pest the next year. If the affected spot is not too large it is well to disinfect the soil with bisulfid of carbon. This is applied by pouring one ounce each into holes placed two feet apart all over the land to be treated. These holes should be about one foot deep and can be made with a small crowbar or dibble. After pouring in the liquid, the hole should be closed by pressing the earth into it with the foot.

If, however, the pest has obtained a foothold in several vineyards of the district, or in a large vineyard, it is practically hopeless to attempt to eradicate it. In this case all we can reasonably hope to do is to delay the spread of the pest as much as possible, and in the meantime to place all new vineyards on a permanently phylloxera-resistant basis. Every infested spot in the district should be diligently sought out and treated. The treatment consists in digging up and burning every vine in each spot which shows symptoms of attack, together with at least three rows of apparently healthy vines surrounding them. Disinfection of the soil of these spots by flooding or with bisulfid of carbon is then advisable wherever practicable, but in any case these spots should be strictly isolated in all farming operations. In cultivating the healthy parts of the vineyard, to pass through the infested spots with plows or hoes is a most effective method of accelerating the spread of the insect.

The search for infested spots is most easily and thoroughly done in July, or August, as at that time the shortness of growth in the "oil-spots" is most readily detected and the insects are easily found, as they are in large numbers on the surface roots and generally also on the trunk of the vine just below the surface of the soil. The search for and destruction of infested spots should be repeated every year; and if commenced in the early stages of infestation and prosecuted with sufficient thoroughness in every vineyard throughout a district, will effectually prolong the life of the bulk of the vines for many years. As soon as the actual presence of the phylloxera in a district is known and all hope of permanently eradicating it is abandoned, the embargo should be modified to the extent of admitting vine *cuttings*. These

should be introduced, however, under strict quarantine regulations, including disinfection by responsible and properly instructed persons. Rooted vines, or cuttings with pieces of old wood attached, should still be kept out, as they can not be disinfected with any certainty.

3. However conscientiously and completely these measures are enforced, a time will arrive sooner or later when the cost of inspection and eradication will be greater than any benefit to be derived from them. We are then face to face with the third set of conditions; we must accept the phylloxera as a permanent inhabitant of the district, and simply consider the best method of growing our vines in spite of its presence. By this time all embargo or quarantine regulations are useless and should be repealed.

Of the many thousands of methods proposed and tested for maintaining a vineyard in spite of the phylloxera, but very few have been of the slightest practical value, and only four are at present used to any important extent. These methods are:

1. Injection of carbon bisulfid;
2. Flooding or submersion;
3. Planting in sand;
4. Planting resistant vines.

The first two methods aim at destroying the insect; the last two at rendering the vines immune to their attack. As neither of the insecticidal methods can be applied with sufficient thoroughness to completely eradicate the pest without also killing the vines, the treatments have to be repeated every year in order to destroy the offspring of the few insects which escaped the treatment of the previous year. For this reason these methods are being abandoned everywhere, especially in all new plantings, in favor of the others, which after the vineyard is properly started, involve no further expense; and as planting in sand is of very limited and local applicability, it may be said that at present the only method that need concern grape-growers in California very seriously is the use of resistant vines.

Bisulfid of Carbon Method.

Bisulfid of carbon is a liquid which volatilizes very rapidly at ordinary temperatures and gives off a poisonous and highly inflammable vapor. This vapor is heavier than air and therefore gradually replaces and saturates the air in the interstices of the soil when the liquid is injected. It is used at the rate of from one hundred and twenty-five pounds to two hundred and fifty pounds per acre, and may be applied at any time except during blossoming and ripening of the fruit. Two treatments, one directly after the vintage and the other a week or so before blossoming, give the best results. The liquid is applied by pouring from one-fourth to three-fourths of an ounce into holes made from

18 to 24 inches apart all over the vineyard, care being taken not to put any nearer than one foot from a vine. The holes are made from 12 to 15 inches deep, and are closed immediately after pouring in the liquid by pressing the soil with the foot. The holes may be made with an iron rod or dibble; but, where the method is employed on a large scale, special injectors are used, which much facilitate the work. The injections are best made when the soil is fairly firm, and when it is neither very wet nor very dry. This method succeeds only in rich, deep, loose soils, and can not be used successfully in soil containing much clay, or on dry, rocky hillsides or when the soil is saturated with moisture. It is most effective in sandy soils, where the nature of the soil is itself unfavorable to the insect. It is least successful in warmer locations, where the insect is most prolific and most harmful, and is used chiefly in the cooler locations where the phylloxera does least damage. Vines which are much weakened by the attacks of the insects can not be successfully treated, and all treated vines require fertilization and most thorough cultivation. The annual cost for material alone would be from $15 to $25 per acre, at the present market price of carbon bisulfid.

Submersion Method.

Submersion is a cheaper and more effective method of controlling the phylloxera, but is necessarily applicable to but few locations, and even where most successful is gradually giving way to the more satisfactory use of resistant vines. Its chief use is to preserve vineyards which are already in bearing, and it may be of use temporarily in some locations in California. In submersion the vineyard must be continuously covered with at least six inches of water, as the object is to drown the insects, that is, to kill them by depriving them of air. If the surface becomes exposed even for a brief period, air will be absorbed and the insects given a new lease of life. In very porous soils submersion is impracticable on account of the large amount of water required, and ineffective for the reason that the rapid passage of the water carries sufficient air into the soil to keep the insects alive. Submersion is most effective in destroying the insects when they are in their most active condition, that is, in summer. At this time, unfortunately, the vine is also most sensitive to injury. The most favorable time, then, for submersion is as soon as the vines have ceased active growth and before the phylloxera have entered their hibernating or dormant condition. This in most parts of California will be some time in November. At this period the flooding need last but a week or ten days; a month later, two or three weeks; while during the remainder of the winter little good results unless the submersion is prolonged for thirty-

five or forty days, and indeed in some soils of the extreme south of France two months has been found necessary. As the insect is most susceptible in midsummer, it was at one time thought that a copious irrigation at that time sufficient to destroy most of the insects without injuring the vines could be effected. At present a flooding in July for not exceeding forty-eight hours is practiced in a few places, but only to supplement winter flooding, or the injection of bisulfid. The insecticidal value of the short submersion which the vines will withstand at this time seems to be very slight. Its main value seems to be in prompting a vigorous growth of new rootlets to replace those that have been injured.

Planting in Sand Method.

Though no thoroughly satisfactory explanation has been given, the fact is established that in certain very sandy soils vines are uninjured by phylloxera. All sandy soils are unfavorable to the increase of the insect, and vines planted in them die more slowly than in others; but for complete immunity the soil must contain at least sixty per cent of siliceous sand. The looser and more fine-grained the sand, the more resistance it offers to the insect. Sands containing notable quantities of clay, all those in fact which have a tendency to form lumps or "cake," offer less resistance.

Resistant Vines.

The most satisfactory method of combating phylloxera is the use of resistant vines, because it is applicable to all conditions and is the most economical in the end. A resistant vine is one which is capable of keeping alive and growing even when phylloxera are living upon its roots. Its resistance depends on two facts: 1st, that the insects do not increase so rapidly on its roots; and, 2d, that the swellings of diseased tissue caused by the punctures of the insects do not extend deeper than the bark of the rootlets and are sloughed off every year, leaving the roots as healthy as before. The wild vines of the Mississippi valley states have evolved in company with the phylloxera, and it is naturally among these that we find the most resistant forms. No vine is perfectly immune in the sense that phylloxera will not attack it at all; but on the most resistant the damage is so slight as to be imperceptible. The European vine (*Vitis vinifera* L.) is the most susceptible of all, and all the grapes cultivated in California, with a few unimportant exceptions, belong to this species. Between these two extremes we find all degrees of resistance, which is expressed by a series of numbers ranging from 20, indicating the highest possible resistance, to 0, indicating the utmost susceptibility. The following table shows the resist-

ance (according to Viala and Ravaz and other authorities) of some of the best known species and varieties:

Comparative Resistance to Phylloxera.

Species—Wild Vines.		Cultivated Varieties and Hybrids.	
Vitis rotundifolia	19	Gloire de Montpellier (Riparia)	18
Vitis vulpina (Riparia)	18	Riparia × Rupestris 3309	18
Vitis rupestris	18	Rupestris Martin	18
Vitis Berlandieri	17	Rupestris St. George	16
Vitis æstivalis	16	Riparia × Solonis 1616	16
Vitis labrusca	5	Solonis	14
Vitis californica	4	Lenoir	12
Vitis vinifera	0	Isabella	5

The degree of resistance necessary for the production of good crops varies with the character of the soil. The resistance expressed by the numbers 16 to 20 is sufficient for all soils. A resistance of 14 or 15 is sufficient in sandy and moist, rich soils, where the vine can readily replace the rootlets as fast as they are destroyed. Fairly successful vineyards have been established with vines having a resistance of less than 14, but as the vines become old the lack of resistance is generally shown by a weakening of the vine and a falling off of the crop. Many vineyards in the south of France grafted on Lenoir which formerly bore well, have now to be treated with injections of bisulfid of carbon. For the above reason it is advisable to reject all vines with a resistance of 13 or under, especially as vines with greater resistance can now be obtained for practically all conditions.

Resistant vines are of two kinds: (*a*) Those which are grown for the grapes they produce, and (*b*) Those which are useful only as stocks on which to graft the non-resistant varieties. The former are called "*Direct producers*," and the latter "*Resistant stocks*."

(*a*) *Direct Producers.*—When the phylloxera commenced to destroy the vineyards of Europe, the natural attempt was made to replace them with the varieties of vines which had proved successful in the United States, where the insect was endemic. These varieties, however, all proved unsatisfactory. Some, like the Concord and Catawba, were insufficiently resistant, and although they could be grown where the severe cold of winter impeded the prolificness of the phylloxera, they quickly succumbed in the milder grape-growing sections of Europe.* Most of them were poor bearers compared with the prolific European vines, and finally the character of their fruit differed so widely from

* In California these and other Labrusca varieties and hybrids resist very little longer than Vinifera vines.

what Europeans were accustomed to, that there was little sale for the fruit, and the wine could compete with only the very poorest quality of Vinifera wines, and brought a very inferior price. A few of the varieties introduced during that first period are still grown to a limited extent in France, chiefly the Othello and the Lenoir. They are being gradually abandoned, however, as their crops are unsatisfactory, and in many localities can be maintained only by the aid of injections of bisulfid. For some years the search for a suitable producer was almost abandoned by practical men, the use of resistant stocks having been so fully successful. Lately, however, renewed efforts have been made and several new direct producers are being advocated and planted to some extent. The merit of these new varieties, however, is chiefly their resistance to Peronospora and black rot. Phylloxera resistance is considered of much less importance by their most ardent advocates, and indeed the advice is generally given to graft some of the best of these direct producers upon phylloxera-resistant stock.

(*b*) *Resistant Stocks.*—Though high resistance to phylloxera is essential in a grafting stock, there are other characteristics equally necessary. The Rotundifolia (Scuppernong), which has the highest resistance of any vine, is useless as a stock on account of the impossibility of grafting it with any Vinifera variety. This is due to a lack of *affinity*, which means a lack of similarity in structure and composition between the tissues of the stock and those of the scion. This lack, in extreme cases, results in an imperfect and temporary union, but when not excessive, only in a slight decrease of vigor. The affinity is not perfect between Vinifera varieties and any resistant stock, but in the case of Riparia and Rupestris is generally sufficient to insure permanence to the union, and the slight decrease of vigor consequent often results in an increase of fruitfulness. It is for this reason that certain varieties when grafted on resistant stocks, especially on Riparia, often bear larger crops than when grown on their own roots. Not all varieties of Vinifera have the same affinity for the same stock. For this reason it is desirable to be cautious about making new or untried grafting combinations on a large scale. Some varieties, such as Carignan, Petite Sirah, Clairette, and Cabernet Sauvignon, do excellently on all stocks; while others, such as Mondeuse and Gamay, do not make a very good union with any of the thoroughly resistant stocks. The Petit Bouschet and Cinsaut make very poor unions with any variety of Riparia, but do fairly well on Rupestris St. George. The Pinot Noir makes a vigorous growth upon Rupestris St. George, but bears much more prolifically upon Riparia Gloire; while the Mataro does not bear on Rupestris St. George and makes poor unions with Riparia Gloire.*

* Reconstitution du Vignoble, par. P. Gervais. 1900.

Selection.—A very serious defect of many resistant stocks is a slender habit of growth. This is true of most of the vines found growing wild, and cuttings from such vines make poor grafting stock for the stout Vinifera varieties, which will produce a trunk four inches in diameter while the stock is growing only two inches. This is particularly true of the wild Riparias. For this reason great care has been exercised in selecting the stronger-growing vines, and at present we have selected Riparia varieties which almost equal Vinifera in the stoutness of their trunks. The best of these are the Riparia Gloire de Montpellier and Riparia Grande Glabre—the first of which has given the best results in California.

Adaptation.—The European vine is remarkable among cultivated plants for the wide range of soils in which it will succeed. We find vineyards producing satisfactory crops on the lightest sands and on the heaviest clays, on the dry hilltops and in the low, moist plains. This is not the case with resistant stocks. Some, such as the Rupestris varieties, are suited to the driest soils; others, like the Riparia varieties, grow well only in rich, moist soils. The question of adaptation, then, of resistant stocks to various soils is of the greatest importance if we are to obtain the best results.

After rejecting all unselected and unnamed varieties, such as the ordinary Rupestris and Riparia, which have caused so much disappointment and loss on account of their poor growth, and all insufficiently resistant varieties, such as Lenoir, which have succeeded only in the richest soils, our choice of a resistant for a particular soil, climate, and scion must depend on its qualifications as regards *affinity* and *adaptation*.

After testing thousands of varieties and hybrids originated in Europe and America, a few have been selected as the best for practical purposes. In France a fairly good resistant stock has been found for nearly every soil. In California little systematic work has been done in this respect, and we still have the intricate problems of *adaptation* to solve for most localities. We can, however, profit to some extent by the experience of Europe, and some of the best varieties have been partially tested here and give great promise.

Disinfection of Cuttings.

The most effective method of treating cuttings suspected of being infested with phylloxera is to expose them to the fumes of bisulfid of carbon. The treatment with liquid insecticides is not nearly so reliable, as Professor Hilgard pointed out many years ago, on account of the difficulty of wetting the buds of many varieties, owing to their protective covering of woolly hairs.

The method of using the bisulfid is as follows: Place the cuttings in a barrel, vat, or box made tight by means of a thick coat of paint, or of paper pasted on the inside. On top of the cuttings place a saucer or other shallow dish, and into this pour the bisulfid of carbon. An ordinary saucer will hold enough for a box three feet cube or a two-hundred-gallon vat. For larger receptacles it is better to use two or more saucers. Deeper vessels will not do, as the saturation is not sufficiently rapid. After pouring the bisulfid into the saucer, cover the box with an oiled canvas sheet or other tight-fitting cover, and allow to stand for from forty-five to ninety minutes. At the end of this time there should be a little of the bisulfid left. If it has all evaporated this is proof that insufficient was used. No flame lights should be used, as the liquid burns easily and the fumes form an explosive mixture with the air. Care should be taken not to spill any of the liquid on the cuttings, as it may kill them. It is advisable to cut off about half an inch of the lower end of the treated cuttings before planting, as the vapor injures the open pith. Besides disinfecting the cuttings in this way, all the packing material in which they come should be burned or, if valuable, dipped in boiling water. Practically, it is impossible to disinfect rooted cuttings satisfactorily on account of the difficulty of killing all the phylloxera without seriously injuring the vine roots.

THE VINE HOPPER.

(*Typhlocyba comes* Say.)

The vine hopper (often called incorrectly the vine thrips) is the most widely distributed and most uniformly present of all the grape insects occurring in the State. It occurs in injurious numbers, however, chiefly in the Sacramento and San Joaquin valleys. It is also present in the coast counties, but rarely in sufficient numbers to do much injury. Another larger species (*Tettigonia atropunctata*) occurs in these localities and sometimes does considerable injury in the early part of the season.

The principal injury occasioned by this insect is due to the extraction of the plant juices. These are sucked out by means of a sharp beak or proboscis, which is inserted into the plant tissues. The first evidence of injury is a pale spot around the point of puncture. As these spots become more numerous the leaf assumes a variegated appearance, due to these pale spots, which indicates a lack of chlorophyll or green matter. As the injury increases the leaf becomes pale yellow in color, and later dries up and falls to the ground. The leaves first attacked, and those which suffer most throughout the season, are about the crown of

the vine. In the vines thus infested, all the leaves within a radius of a foot or two from the center of the vine have dried up and many have fallen off by the end of June or July, thus exposing the fruit. This early loss of foliage prevents the berries from maturing properly. The sugar content of the grape is much reduced, and in table varieties the characteristic coloring, which is important, is not attained. In addition, the fruit is badly soiled by the excrement of the hoppers—which serves to hold dust and dirt or offers suitable conditions for the growth of fungi—and often this covers the leaves so thoroughly as to interfere with respiration. The loss of leaves, or any interference with their normal functions, also prevents the proper ripening of the canes for the next year's wood, and thus the vine may require a year or more to recover from severe cases of hopper injury.

This insect is not more than a tenth of an inch long and of a pale yellow color, prettily marked with irregular red markings. They are usually found on the under side of the leaves, and if these are turned over carefully the insects may be seen. They are very readily disturbed, and often emerge from a vine in swarms, so that they are not likely to be mistaken for any other insect pest of the vineyard.

FIG. 3. The grape leaf-hopper.

Life History.—The life history of this insect as it has been worked out in this State during the past year is, briefly, as follows:

Hoppers which have reached full growth on the vine during the fall or late summer remain in the vineyard or vicinity during the winter season. During the colder days they are more or less dormant and will be found hiding under the leaves, or other rubbish in the vineyard, or sheltered in the vegetation along the bordering fences or roadsides.

During the warmer days of winter they become fairly active and will be found feeding on whatever vegetation happens to be growing among the vines or in the vicinity.

As soon as the vines come into leaf in the spring, they leave their more varied food-plants of winter and attack the vine exclusively. After feeding upon the grape foliage for about a month, egg-laying begins. This in the Lodi section during the past season was about May first. The eggs are laid just beneath the epidermis, on the lower side of the leaf, rarely on the upper surface. They may be distributed anywhere over the surface and are most difficult to see unless one is familiar with their appearance. We have counted more than seven hundred of these eggs in a single leaf. One hopper will lay, on an average, seventy-five to one hundred eggs, during a period of from one to two months. The eggs from these over-wintering hoppers require about

twenty days to hatch. Then the young or nymph appears and begins at once to feed upon the leaves. It is a very small creature, white in color, with conspicuous red eyes. After feeding for a few days it molts or sheds its skin. Altogether it molts five times, requiring a period of from seventeen to twenty days before the last molt, when the full-fledged winged hopper is produced.

After feeding for a couple of weeks as an adult hopper, pairing begins and a week later another set of eggs is deposited. These require but from eight to twelve days to hatch, a shorter period than the first lot required, probably on account of the higher temperature later in the summer. Thus the life cycles are repeated. Nymphs arising from the eggs laid by the over-wintering hoppers began appearing about the middle of May, and those from the following brood about the middle of July, making two broods during the season.

CONTROL MEASURES.

Farm Practices.—Since the over-wintering hoppers are sheltered in large numbers by the leaves which are blown together in bunches in the vineyard, and other rubbish along the borders, clean cultivation will help to reduce their numbers. The hoppers depend for food upon what they can obtain in the vineyard or vicinity, and if the weeds and other vegetation are kept down many will starve or be obliged to go elsewhere for food. When the vineyard is plowed in early spring before the vines come into foliage, the hoppers will all leave the vineyard and feed upon the nearest available vegetation, which is usually about the borders. If these borders and roadsides could be kept free and a general movement for clean culture inaugurated in a neighborhood, it might do much to prevent the hoppers from becoming excessive, but because of the possibility of extensive migrations in the spring the work of any individual grower might be of little avail, though such migrations did not occur at Lodi the present season and individual work would undoubtedly have been useful.

The Hopper Cage.—So far as the work has progressed this year the most satisfactory method of control is in the use of a hopper cage to be used in the early spring when the young shoots of the vine are about four or five inches long. This is to be supplemented, if necessary, by spraying for the first brood of nymphs early in June.

The hopper cage (Fig. 4) consists of a frame work of laths over which is tacked a double layer of mosquito wire netting or a single 20-mesh wire screen. The bottom consists of a shallow pan or tray made by turning up about an inch of the edges of a sheet of light galvanized iron. One entire side of the cage is left open, and there is a V-shaped opening in the tray at the bottom which allows the cage to be pushed over the

vine. The base of the V-shaped opening in the bottom is padded with leather and the vine is bumped and the hoppers jarred off, at the same time that the cage is being swung into position. The sides of the cage and the tray at the bottom are smeared with crude oil, and the hoppers as they are jarred off are caught in the oil.

If there is a breeze blowing the cage can be operated with the open side facing the wind and practically no hoppers will escape. If, however, the day is calm and warm and the hoppers are particularly active

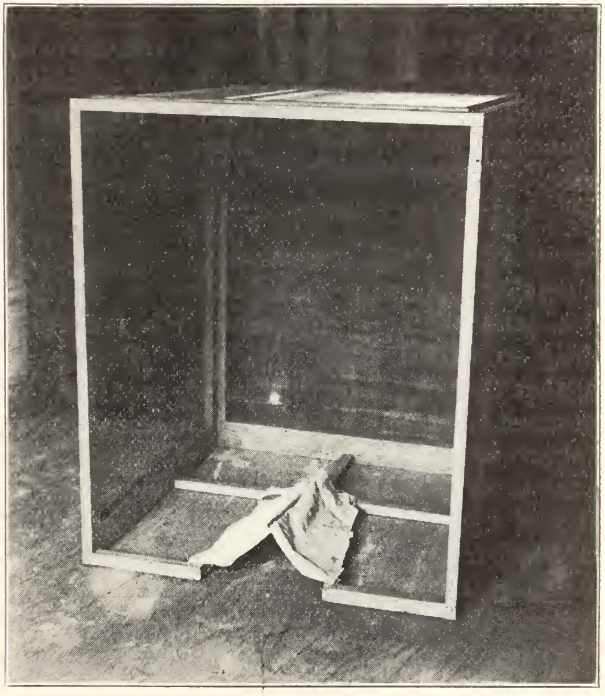

FIG. 4. The hopper cage.

a curtain can readily be dropped over the open side as the cage is pushed onto the vine, and it will prevent any from escaping.

The V-shaped opening which might allow hoppers to drop to the ground in front of the vine can be covered with canvas, as follows: Take two pieces of canvas about the shape of the opening and a little wider. Double this once on itself and between the two layers sew in pieces of three-fourths inch rubber tubing transversely. These are then firmly tacked on the sides of the opening as shown in the figure. This will allow the cage to be pushed in on the vine and the flexibility of the tubing will bring the canvas immediately into position again. This, with the curtain in front, shuts off all possibility of escape.

This device can be used to advantage only when the vines are headed

some little distance from the ground so that the bottom of the cage can be pushed under them. While it is generally conceded that this is the proper way to prune most vines, there are still some vineyards in the State where the vines have been headed immediately at the ground, and some others have been given this form by frost. For such vines, if the cage is to be used at all, it must be used with no bottom, or, at least, a less complete one than the cage described.

This cage should be used in the early spring when the shoots are not more than four or five inches long. At this time all the hoppers will be found on the vines and they have not yet laid any eggs. The cage need not be much larger than the diameter of the vines after pruning. The size of the cage and the opening at the bottom should be made according to the size of the vines to be treated.

This cage can be used at comparatively little expense—there being practically no cost for materials—as the chief outlay is the time of the men employed in handling it. Such a cage can be manipulated by a couple of men, and for small vines, four or five years old or under, it may be handled by only one. Four or five acres can be covered in a day and the oil used can be bought for a trifle.

If this cage is conscientiously used it will catch from 85 to 95 per cent of the hoppers, and this, at a time before any eggs have been laid, ought to control the situation for the season. No migrations were observed during the past season until about the middle of July, and if the vines have not already been injured, they will not suffer much loss from an attack at this time or later.

Spraying.—If for any reason the above method has not been used, or satisfactorily done, the next most successful method is to spray for the first brood of nymphs or young. The time for doing this during the past season at Lodi was about the first of June, but the date will vary with the season and location. The sprays which were found to be satisfactory were the whale-oil soap solution and the resin spray. The materials used in these sprays were one pound of soap or resin to fifteen gallons of water. About one-fourth of a pound of ordinary lye should be used to each pound of resin to make it dissolve thoroughly.

An "upper shot" spray should be used, and the best type of nozzle for this is an eddy chamber Vermorel, where the liquid is turned at right angles in the chamber. This style does away with anything to catch among the canes, and such a nozzle may be poked anywhere through the vine without being caught.

Thoroughness is most important here, since the spray will kill no more than it hits. The under side of every leaf must be wet with the solution. If this is done by the first of June when the growth is small, it is not an exceedingly difficult task. This spraying is expected to kill

the nymphs only. It will, of course, kill a few adults, but the number of these will be very small. In addition to the adults which escape, there are eggs at this time which the spray will not prevent from hatching. While this means of control will kill a very satisfactory percentage of the nymphs, many adults will escape, and the eggs will be left to hatch later.

The advantage of the cage method is that it is more thorough and effective. The hoppers are attacked at a critical time; *i. e.*, when all adults are in the vineyard; and as they have not commenced to breed or to lay eggs the work is effective in greatly diminishing the numbers of succeeding generations.

THE IMPORTED GRAPE-ROOT WORM.

(*Adoxus vitis* Fourcroy.)

This pest of the vine has been reported from different parts of the State for a number of years, but until a year or two ago it was unknown as a root feeder. In our literature it has commonly gone by the name of flea beetle, and probably most growers know it by that name. It is not, however, a flea beetle at all, since it neither jumps as indicated by the name, nor is its life history similar to that of a flea beetle.

FIG. 3. Adult of the grape-root worm.

It was called by Matthew Cooke, in his book entitled "Injurious Insects of the Orchard and Vineyard," the "Imported Grape Flea Beetle." Since, however, it is a root beetle rather than a flea beetle and is probably an imported insect, and in its life history is almost identical with *the grape-root worm* of the Eastern States, we propose giving it the common name of Imported Grape-Root Worm.

This insect has done considerable damage in this State within the past two or three years, and promises to be a serious enemy of the vine-yardists unless held in check. The grape-root worm of the Eastern States, identical in all important respects with this one, is one of the most serious pests the grape-grower in that region has to fight.

The insect injures both the roots and the growing parts of the vine above ground. It is a small beetle, about one-fifth of an inch long, and either black or brown in color. There is no mistaking its identity from

FIG. 6. Leaf eaten by root beetle.

the way it eats out chain-like strips from the leaf, or gouges out similar strips on the shoots and other growing parts.

Life History.—The adult beetle appears in May, having emerged from the ground where it has been since the previous year, and where it has passed through the larval and pupal stages. It begins at once to feed upon the leaves, eating out narrow slits about one-twentieth of an inch wide and from one-fourth to three-fourths of an inch long. It attacks the shoots, petioles, pedicels, and to a less extent the berry itself in the same way.

After feeding for a couple of weeks, egg-laying begins. The eggs are deposited on the inner bark, or in crevices, usually beneath two or three layers of the old bark. They are laid in clusters of from four or

five to twenty-five or thirty. Hatching occurs in from eight to twelve days, when the young larva appears and crawls, or possibly drops, to the ground and makes its way to the roots.

After having burrowed its way through the ground to the roots it begins feeding, probably mostly on the smaller roots at first, later attacking the larger ones and eating out strips of the bark. This feeding continues until winter, when the larva becomes dormant, finally changing to the pupa in the following spring. Pupation took place this year during the last of April, and continued well into June. The first beetles emerged about the first of May.

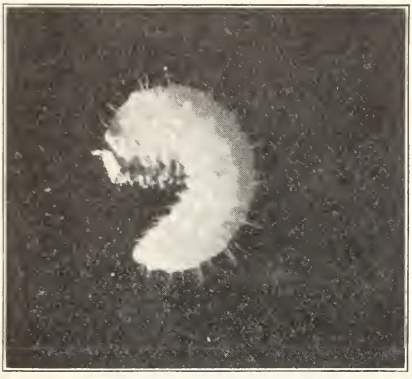

FIG. 7. Imported grape-root worm.

The most serious injury to the vine is due to the work of the larvæ on the roots, the small roots being eaten off entirely, thus preventing the plant foods, taken up directly by the root hairs, from reaching the growing parts of the vine. The larger roots are injured by having strips of the bark eaten off, in bad cases of injury scarcely any of the bark being left. Vines thus affected show a stunted condition, the canes failing to attain a normal growth, and in severe cases the vines may be killed outright.

Control Measures.—Since the insect comes to the surface and feeds upon the leaves and other growing parts of the vine an opportunity is offered for fighting it in this stage. The beetles are very readily jarred from the vine and may be captured if something is placed under the vines in which they can be caught.

The hopper cage, described on page 114, checked the development of the beetles in a vineyard near Lodi during the past season. This means has the advantage of capturing the hoppers also, which are more than likely to be present, at the same time. The fact that the beetles keep emerging from the ground for a month or so may make more than one operation necessary. Fortunately, however, the beetles are usually confined to a limited area of the vineyard, so that it is not necessary to go over a large area. When the beetles alone are to be caught, simply the tray on the bottom of the cage can be used. Handles may be attached directly to the tray for convenience in manipulating.

These beetles may also be fairly well controlled by an arsenical spray. They are rather resistant to poisons and a strong dose must be used. We obtained fairly satisfactory results by using lead arsenate in the ratio of five pounds to fifty gallons of water. Paris green may

be used and the ratio of at least one pound to one hundred gallons of water is required. This spraying should be done as soon as the first beetles make their appearance in the spring.

Since the pupæ are within four to eight inches of the surface much good can be done by thoroughly stirring the ground within a radius of two or three feet about the vine for a depth of six inches or more. If this can be done at the proper time when they are in the pupal stage it will no doubt destroy many.

It has been suggested and some experiments seem to prove that if the land is left uncultivated about the base of the vine, the beetles will be unable to break through the crust at the surface. We have not had opportunity to demonstrate this point. If successful it must depend largely upon a type of soil that will form a hard, impenetrable layer at the surface.

HAWK MOTH LARVÆ.

These larvæ are occasionally met with over large areas every year in California, and in certain restricted areas they sometimes become exceedingly abundant and may completely defoliate a vineyard. The worst case that has come to our notice this year was on a vineyard belonging to the California Wine Association near Reedley.

FIG. 8. Showing one vine in a 75-acre vineyard defoliated by Hawk Moth larvæ.

Here seventy-five acres of vines were completely stripped of their foliage and scarcely an entire leaf was left on the area. As many as one hundred and fifty full-grown larvæ were counted on a single vine. In this case the owners were not aware of the extent of the danger until the worms had become nearly full grown, and most of the damage done. At this time, however a gang of about two hundred men was set to work picking them off the vines, and worms were carried away by the cartloads and burned. The species concerned here was the Achemon Sphinx (*Philampeles achemon* Drury), which is the most common species attacking the grapevine in the State.

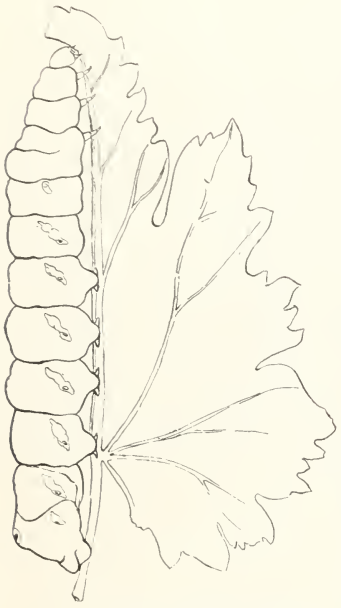

FIG. 9. Hawk Moth larva. (*Philampetes achemon* Drury.)

These caterpillars may be found on the vines late in May, and during the larger part of June. The larvæ are green in color, like the leaf, and are therefore not readily distinguishable when they are small. They soon increase in size, however, and their work on the leaves becomes noticeable. While small, these larvæ may be distinguished by a large horn on the posterior end of the body, but this is lost during a molt before they are quite full grown.

Life History.—These insects hibernate in the pupa or chrysalis stage, and while in the ground may be distinguished as large cylindrical objects of a dark brown color (Fig. 10). About the middle of May or thereabouts they emerge from these chrysalids in the ground as large and handsome moths (Fig. 11). These are the common moths that poise over flowers at dusk. They are particularly attracted by petunias, and it has been suggested that they might be captured in large numbers about these flowers.

The eggs are laid on the vine, and the larvæ, upon hatching, begin immediately to feed upon the grape foliage. Since they are voracious feeders and grow to a very large size, three inches long or more, they consume an enormous quantity of leaves. This year most of the larvæ were mature by the twentieth of June. When mature they repair to the ground, where they pupate. In the vineyard already mentioned, there appeared a second brood of caterpillars during the middle of July. None of these reached their full growth, dying from some unknown cause while they were but an inch and a half long. They

had all disappeared when we visited the vineyard on August the first, and according to the owners they simply dried up. It was probably due to a fungous disease which often destroys these caterpillars in great numbers. We also found these caterpillars in the vineyards about Lodi in June and August, indicating that there are two broods in a season.

FIG. 10. Chrysalids of a Hawk Moth (*Philampeles achemon* Drury).

Control Measures. Where there are but occasional specimens of this insect found in the vineyard, the cheapest and most practical way is to pick them off by hand. Where there are immense numbers of them, as in the case mentioned at Reedley, hand picking becomes a laborious task. In the latter case a thorough spraying with a strong arsenical spray applied just at the time they are hatching, will check them before they can do a great deal of harm.

FIG. 11. Hawk moth (*Philampeles achemon* Drury).

If the adult moths are particularly attracted by the petunias, as seems to be the case, a means of capturing them in this stage may be found in poisoning the flowers thoroughly with some soluble poison or by catching them in traps. The effectiveness of these methods will

depend upon whether many of the eggs are deposited before they fly about much. While numbers of moths may be caught in this way, it is doubtful if it will ever prove of very great practical value.

GRASSHOPPERS.

These insects do a great deal of injury to vines every year in some parts of the State. This year they have been abundant everywhere and considerable damage has resulted. In a vineyard twelve miles east of Fresno forty or fifty acres of vines were completely defoliated. These insects are generally most troublesome in new vineyard sections or localities surrounded by large areas of uncultivated land.

FIG. 12. Vineyard defoliated by grasshoppers.

Life History.—The eggs of the grasshoppers are laid in the ground in the late summer or fall, and a decided preference is shown for uncultivated land. These eggs are laid in capsules containing a large number, and are protected by a frothy or gummy substance which prevents them from being affected by unusual weather conditions. The eggs remain in the ground during the winter and hatch the following spring. The young grasshopper is similar in appearance to the adult, except that the wings are lacking, but these are gradually acquired with molting. There is usually but a single generation, though in some parts of the State there are probably two.

Control Measures.—Grasshoppers may be controlled by poisoned bait, by spraying heavily a few rows along the border of a field, by the hopper dozer, by burning waste feeding areas, and by the introduction of turkeys. Various combinations of two or more of these measures may be used to fit particular cases. Of the methods used to protect vineyards, poisoned bait is probably the most common. This consists of bran and molasses or other sweet substance poisoned with arsenic and distributed in handfuls about the vine. The proportions are as follows: forty pounds of bran, two gallons of cheap molasses, and five pounds of arsenic. Cheap glycerine may be used to prevent the mixture from drying. If the grasshoppers are entering in well-defined swarms and caught on the first few rows they may be killed by heavily poisoning a few rows on the side at which they are entering. Some growers find turkeys to be the most successful destroyers, and if the hoppers are not too abundant, this method is probably as good as any, particularly at a time when the hoppers are still small.

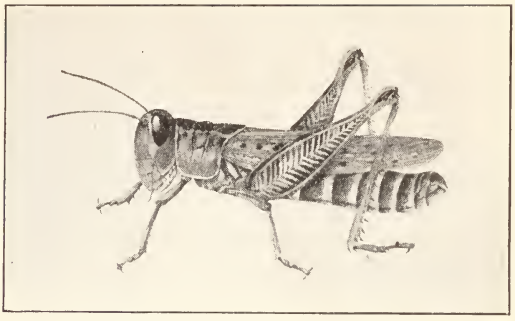

FIG. 13. Valley grasshopper (*Edaleonotus enigma*).

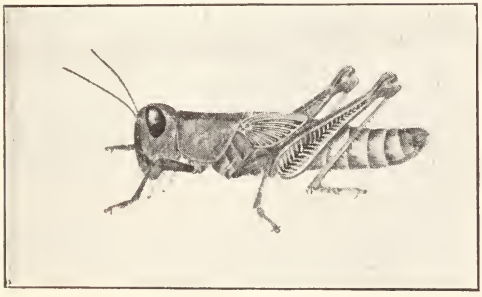

FIG. 14. Differential grasshopper (*Melanoplus differentialis*). Young.

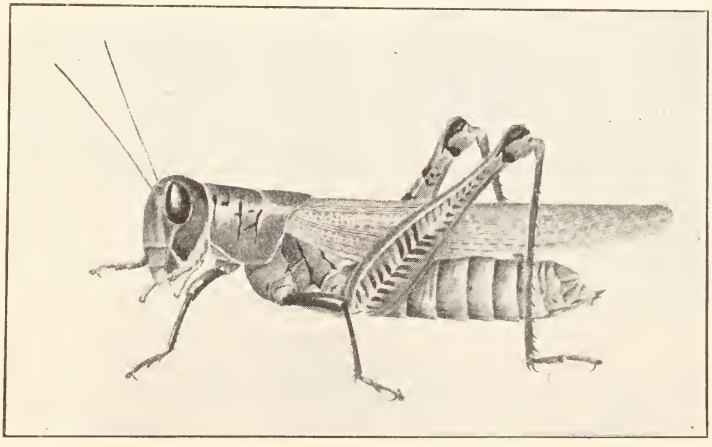

FIG. 15. Differential grasshopper (*Menanoplus differentialis*). Adult.

Those who have been most successful with turkeys go about using them in a systematic way. They turn in a band of them early in the morning and let them feed for a couple of hours, then drive them into a cool barn where they remain through the heat of the day. In the evening they are again turned into the vineyard for two or three hours and again confined in an inclosure, so that they obtain a straight grasshopper diet supplemented by gravel, to which they have access while not in the vineyard.

When vineyards adjoin, or are near, large uncultivated tracts, where the grasshoppers hatch out in large numbers, it is best to look beyond the vineyard in planning the control. This may mean more or less organized effort in burning off or plowing such uncultivated lands. For a full account of this and other methods of grasshopper control the reader is referred to Bulletins Nos. 142 and 170 of this Station.

CUT WORMS AND ARMY WORMS.

These are the larvæ of Noctuid moths, which often become abundant over limited areas and do much damage to vines.

Cut worms and Army worms are terms applied to the same insects in California. In ordinary years they are not present in sufficient numbers to cause much concern, and in such years they are known simply as cut worms. When all conditions are favorable, however, certain species develop in enormous numbers and having exhausted the food supply where they breed, they begin to migrate or march, commonly in a definite direction, as an army in search of new food. When they thus appear in such large numbers and take on the migrating habit they are called army worms.

FIG. 16. Army worm (*Heliophila unipuncta*). The species that was abundant at Lodi this year.

Some of the caterpillars have the habit of climbing up vines and trees and eating off the buds in the early spring. These are called climbing cut worms. Others remain at or near the surface of the ground and feed by cutting off the plants at this point. They are more commonly found in the grass lands, but very frequently attack culti-

vated crops, particularly on land that was in grass the previous year. It is the two former—the climbing cut worms and army worms—that chiefly concern growers of vines.

The climbing cut worms appear in the early spring and eat off the expanding buds. They also feed upon the young leaves as they appear, but an early attack on the swelling buds is when the most serious damage is done, because the removal of the principal bud destroys the fruit and the later buds usually produce sterile shoots. The two commonest species concerned here are *Paragrotis messoria* Harris and *Peridroma margaritosa sauci* Hubn.

The life history of all the species of this group is much the same,

FIG 17. Moths of cut worms.

and they may be discussed together. The majority spend the winter as a partly grown larva. In the spring they again become active and begin to feed after being more or less dormant during the winter. If they are the climbing species they may be found attacking the buds or young leaves of the vine. When they become full-grown larvæ they go to the ground, where they change to pupæ. After two or three weeks in this stage the adult moth appears. These are usually dark colored (Fig. 17), and because they fly about at night are seldom seen.

The eggs are laid mostly on the stems of grasses near the ground. The larvæ hatching from these feed at or near the ground, and since they work mostly at night are not readily seen in their concealed situations during the day. There being plenty of vegetation at this season also they do not interfere seriously with the crop. By fall they become

partly grown and spend the winter in a more or less dormant condition. There are generally two broods of the worms in California and in some cases probably three. Any one of several species, however, may increase to immense numbers, and they are then called army worms.

They appear in large numbers as army worms, generally with the second brood in midsummer. During the past year in the vicinity of Lodi there was a distinct outbreak of army worms appearing simultaneously in a dozen or more different places. In nearly every case these came from grain fields in which they bred, and because of the large numbers and scarcity of food were forced to migrate, and as a result, a number of vineyards were threatened with defoliation. These grain fields or breeding places become pretty well dried up by August, and furnish very little succulent growth for the voracious army worm.

The worms appeared this year during the first week in August. They had been feeding for a week or two in the grain fields, since some were nearly full grown, but had not been observed to migrate until the date mentioned. In one of these grain fields a contagious bacterial disease killed them off by the thousands, and very effectively checked their progress. Portions of a number of young vineyards were defoliated before their presence was realized. The species concerned here was the true army worm of the Eastern States, which bears the scientific name of *Heliophila unipuncta*. In bearing vineyards, besides eating off the leaves, these worms have the pernicious habit of cutting off the stems of the clusters of fruit, which drop to the ground and dry up. In a portion of a bearing vineyard near Lodi, where these pests were present, this unripe fruit was picked up, while still fresh, by the basketfuls and made into jelly.

These caterpillars are mostly dull-colored worms from one to two inches long, with longitudinal strips of black, gray and yellow or reddish brown. There is considerable variation in color in the same species, some being much darker in color. Generally the midsummer brood from which the army worms arise are darker colored than the spring brood. The one present in Lodi and vicinity this year (see Fig. 16) had a broad black velvety stripe on the dorsal side. Below this was a stripe of whitish yellow about one half the width of the former, with its center made up of broken wavy lines. Below this was another narrow stripe of black with the spiracles on the lower edge; back and a little above each spiracle was a conspicuous white spot that on first sight would be taken for the spiracles themselves. Below this is another stripe of light brown, and on the ventral surface a general color of cinnamon brown.

Control Measures.—The cut worm, although belonging to the same group as the army worm, on account of the difference in habits must be controlled in a different way. Since it is those species which acquire

the climbing habit that attack vines, they require a different manner of treatment from those which feed upon plants at or near the surface. Because they actually devour the buds of the vine, the application of a poison spray ought to be effective. However, since the surface on which there may be poison in the case of buds is so small, one worm may destroy most of the buds on an ordinary-sized vine before the dose eaten will prove fatal. Probably one of the best ways of fighting these is to place poisoned bait around the base of the vine. (For the ingredients see under Grasshoppers, page 123.) This will be eaten by the worms in preference to climbing up the vines and destroying the buds. They may also be captured by means of traps. Because of their habit of feeding at night and remaining concealed during the day, pieces of boards may be placed on the ground around the vine and these may be turned over during the day and the worms killed.

In case of outbreaks of army worms the most important and successful means of fighting them is to keep them out of the vineyards entirely. This can be successfully done if they are discovered in time, or if already in one portion they can be kept from spreading over the rest of the vineyard. They travel in immense numbers in a definite direction, coming generally from an adjoining or nearby grain field. If a furrow is plowed along the side of the vineyard to be protected it will effectively stop their progress. This furrow should be plowed as deep as possible, with the vertical side next to the field to be protected. It can be further trimmed with a spade, preferably cutting under slightly, making a smooth surface, over which few, if any, of the worms will make their way. Above this shoulder fine pulverized earth should slope as abruptly upward as possible. If any of the worms succeed in climbing up over the smooth surface made by the spade they will be pretty sure to fall back as they reach this fine loose earth in an attempt to ascend over the projecting shoulder. Postholes should be dug on the straight edge of the furrow every fifteen or twenty feet. The worms in failing to scale the vertical side of the furrow will crawl along in the bottom and fall into these holes. Here they may be killed by pouring in a little crude oil, or by pouring in a little distillate and dropping in a match, thus burning them, or the holes filled in and others dug. They may also be killed in the furrow by sprinkling them with kerosene or by pouring a strip of crude oil along the furrow.

It is most essential in fighting army worms that prompt and vigorous efforts be undertaken immediately, since a day's delay may mean considerable loss and more difficulty in handling the situation. Once they are in the vineyard the vines infested should be heavily sprayed with lead arsenate at the rate of five pounds to fifty gallons of water, or with paris green in the proportion of one pound to seventy-five or one hundred gallons of water. In addition to this the furrow should be

plowed, as already described, beyond the infested portion to check their further spread. If these measures are undertaken promptly, what might be a serious loss can be averted.

FLEA BEETLES.

(*Haltica* sps.)

These beetles have generally been confused with the root beetle already discussed in this bulletin. In these beetles the thighs of the hind legs are enlarged, thus enabling the insect to jump much in the same way as the flea; hence the name. They have frequently been reported as doing damage in the State, but during the past season we have not learned of any important injury done by them. Two or three specimens were taken near Lodi, and while no particular effort was made to collect them, this was all we obtained during the season. Certainly there were no large numbers of these beetles in the sections where our work was carried on this past year. Several growers reported that the flea beetle was doing considerable damage, but upon investigation these were found to be the root beetle. They are said to be particularly abundant in the Sonoma Valley, but we did not have the opportunity of visiting the valley during the present season. There are about a dozen species of the genus *Haltica* occurring in this State, probably the commonest occurring on the vine being the species *bimarginata*. This species is not confined to the grape alone, and during the past year it was exceedingly abundant in many places over the State on the alder. The grape flea beetle of the Eastern States (*Haltica chalybia*) is not known to occur here.

The flea beetle on the grape is commonly of a bluish color, about one-fifth of an inch in length, and is capable of jumping, while the root beetle is either black or brown in color and has no power to jump. The injuries of these two beetles are also readily distinguishable. The flea beetle eats out irregular holes, which may differ much in size and shape, while the root beetle eats out narrow strips of very uniform size and shape. They also present entirely different life histories.

Life History.—The flea beetle passes the winter among leaves or in other situations affording some protection to the adult beetle, and emerges in the early spring and feeds upon the buds of the vine. These may be entirely eaten away or the centers gouged out, thus destroying the buds. After feeding for some time they begin depositing their eggs, generally in the cracks in the bark or at the base of the buds. The larvæ, after hatching out, attack the leaves and eat out holes, as already indicated. They continue to feed as larvæ for three or four

weeks, when they drop to the ground, make a little cell just beneath the surface, and change to pupæ. The beetles emerge a week or two later and these feed upon the leaves. There are probably two generations of the insect each year. Those we obtained were taken as adult beetles in June, which were from eggs laid in the early spring, but whether these remain until winter and hibernate, or again lay eggs, was not determined.

Control Measures.—Since this insect feeds upon the foliage both as larva and adult, it may be controlled by means of a poison spray, either paris green or lead arsenate. The beetles are also easily jarred from the vines and the method described for capturing the root beetle can be used here.

THE GRAPE-LEAF FOLDER.

(*Desmia funeralis* Huber.)

This insect occurs in considerable numbers in some sections of the State every year, but the total injury is not usually very great. During the past season the worst attack that came to our notice was in a vineyard near Reedley, where seventy-five or one hundred acres of vines had a large number of their leaves rolled. On some vines nearly every leaf was found to be rolled and harboring the larvæ of this insect. Occasional specimens were also found near Lodi, but they were not numerous enough to do any important injury.

They may be easily detected in a vineyard by the characteristic rolling of the leaves. One edge is rolled up rather tightly to about half way across the leaf, making a tube less than the diameter of a lead pencil, in which the larva lives. The leaf is always rolled on the under side. The insects feed by eating off the free edge of the leaf in the interior of the roll, so that they are always protected by the outer layers of the rolled portion. The insect hibernates as a chrysalis, appearing and laying eggs upon the vine in the spring. The larvæ of the first brood appear about the first of June. By the twentieth of June at Reedley this year the larvæ had all changed to pupæ. The larva is a greenish-white caterpillar, about an inch long when full grown. They wriggle out of their nests very vigorously when disturbed and drop to the ground. *Larvæ were taken at Lodi in June and August, indicating that there are at least two broods in a season.

*The head and prothoracic shield are light brown in color. On the mesothoracic segment are two pale-brown spots or rings, and beyond these laterally are two larger and darker crescent-shaped spots. There is also a pale spot on the same segment more ventrally and a little forward. On the preceding segment are two large irregular pale-brown spots and one small round spot, also of pale brown. On the penultimate segment there are two dark crescent-shaped spots situated dorsally.

This insect occurs, apparently, throughout the United States. It is very common in the Eastern and Middle Western States, but there is

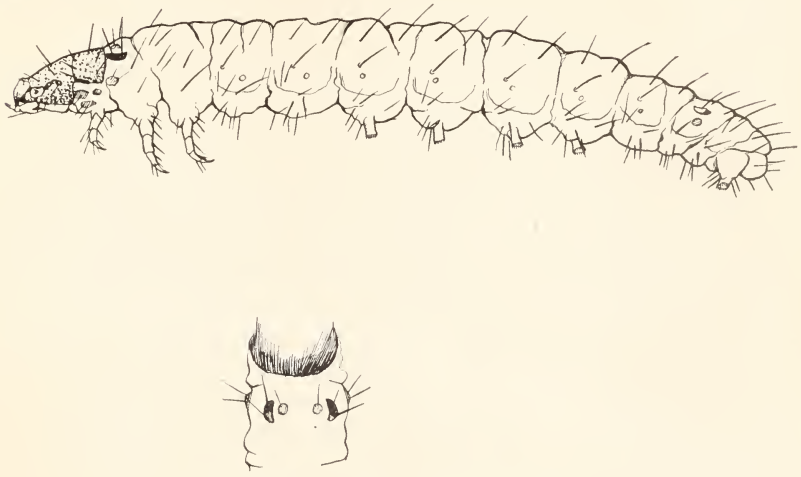

FIG. 19. Larva of grape leaf-roller.

a striking difference in habits between the insect there and what is considered the same species here. In the East, the leaf is simply folded

FIG. 20. Moth of grape leaf-roller, enlarged.

over on the upper surface and the edges sewed down by strands of silk. There the larva feeds by eating off the upper surface of the leaf, thus skeletonizing it. Here the leaf is very distinctly rolled and instead of

eating off the upper surface it feeds on the free edge. According to its habits in this State, *leaf-roller* would be a more appropriate name than *leaf-folder*. Specimens of the moth sent to the Bureau of Entomology at Washington, D. C., were identified by Dr. Dyar as *Desmia funeralis* Huber—the same species that occurs in the Eastern States.

The moth is nearly an inch across the expanded wings, and is black with white markings. There are two white spots on each wing, those on the posterior wings being larger, and in some specimens fusing into a single large spot. There are also two white bands across the abdomen, one about the center and one near the tip. The wings are also bordered with a fringe of white, and the tarsi and apical half of the antennæ are white.

Control Measure.—The only control measure which is likely to prove effective is to spray with an arsenical before the rolling of the leaf is commenced, so that they may be obliged to eat the poison, even though they are within the rolled portion. If they are not too abundant, hand picking or simply crushing the folded portion of the leaves will be the most practical.

LEAF CHAFERS.

Under this head come the rose chafer, and other allied species, which often attack the leaves of the grapevine. The true rose chafer, which often does much injury to vines in the Eastern States, as far as we are aware, does not occur in California.

A species which was very abundant in the neighborhood of Florin during the past season was *Serica mixta* Lec. This insect was not restricted in its feeding, however, to the vine, but attacked a great variety of plants. *Hoplia sackonii* has also been taken in large numbers on vines at Fresno.

The life history of the rose chafer has been carefully studied, and the life history of these allied species may be much the same. The younger stages of these insects are passed in the ground, where the larvæ feed upon the roots of plants, preferably grasses. They are full grown by fall and in the spring ascend toward the surface, where they change to pupæ. Two or three weeks later they emerge from the ground as adult beetles and attack the grape and other plants. A sandy soil is especially adapted for their underground habits. After feeding as adult beetles for two or three weeks they deposit their eggs in the ground and from these the next generation of larvæ emerge and feed upon the roots until fall.

Control Measure.—These insects are rather difficult to control, but a liberal dose of poison will check them if they are not present in great

swarms, as they sometimes occur. The jarring method as described for the root beetle will also prove valuable.

Since these insects feed in the larval state upon the roots of grasses growing along the roadsides or fences or irrigation ditches, much can be done to prevent an outbreak by keeping such places free from vegetation.

WIRE WORMS.

These are long cylindrical worms with a dark brown leathery covering resembling somewhat a piece of rusty wire. They live for a year or more in the ground, feeding upon the roots of plants. They feed upon a variety of plants and are not restricted to grape roots alone. We have taken as many as fourteen of these worms from around the roots of a vine from a foot and a foot and a half from the surface. During the growing season of the vine when the vineyard is free from vegetation these wire worms must feed to a considerable extent upon the roots of the vine. The adult is the well-known click or snapping beetle, the one most commonly met with being about one-half an inch long, slender, and of a dark brown or black color. We have seen immense swarms of these click beetles in a vineyard near Hanford, and when they occur in such large numbers they probably do considerable injury to the vine as root feeders.

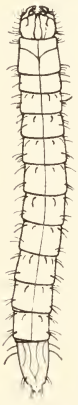

FIG. 21. A wire worm.

When young vines are planted in soil which has previously been in hay or pasture the wire worms may attack the bark just below the surface and kill the vine by girdling it. Rupestris St. George seems particularly susceptible to this form of attack. The vines may be saved if the wire worms congregated around the collar of the vine one or two inches below the surface are collected by hand in time.

Treatment.—We know of no generally satisfactory remedy for these insects. Turning up the soil is recommended for the same insect in the

FIG. 22. Young vine girdled by wire worms.

East, especially in the fall or winter, but such an operation is likely to prove of little value in our climate here. Besides, most of those found around the vines were below the reach of any plow. Clean culture in the vineyard will do as much as anything, since ordinarily they feed upon the roots of grasses and other plants at a comparatively short distance from the surface.

ERINOSE.*

Erinose is a disease of the vine characterized by swellings on the upper surface of the leaves, and corresponding depressions on the lower surface. These swellings, when numerous, cause considerable deformation of the leaves, but not the change of color to yellow or brown which is characteristic of most fungous diseases. Even very badly affected leaves retain almost their normal green color on the upper surface until late in the season. The depressions on the under side are coated with a thick felt-like covering, which, at first pure white, gradually turns rusty and finally becomes dark brown. Generally, the swellings and corresponding depressions are isolated and few in number on the affected leaves, but in severe cases they are numerous enough to become confluent and the whole lower surface is then completely hidden by the felt-like covering. Occasionally, indeed, the felt-like material extends to the upper surface in narrow strips bordering the veins, and may even be found on the petioles and flower clusters.

FIG. 23. Vine leaf affected with Erinose—upper surface.

Most of the specimens received at the laboratory are sent under the impression that they are attacked by a fungus, and, in fact, the coating has a strong superficial resemblance to some fungous growths. A microscopic examination shows, however, that it consists of a mass of hypertrophied hairs or abnormal outgrowths of the epidermal cells of the leaf. They are larger, more abundant, and more persistent than the

* Revised from Bulletin No. 136, by F. T. Bioletti and E. H. Twight.

normal leaf-hairs of the leaf, and differ also in being often branched and usually unicellular. This abnormal growth, in common with similar growths found on other plants, is called an *erineum*, from a Greek word meaning woolly. This is the derivation of the word erinose, which means woolly disease—a very appropriate name. The erinea of leaves were formerly supposed to be of fungous origin, but are now known to be due to the attacks of minute mites. The feeding of these mites exert a stimulating effect upon the epidermal cells of the leaf, which causes them to grow out into the abnormal hair-like processes already described. The mite causing erinose of the vine is known as *Eriophyes vitis*, and is related to the mites causing a similar disease of the walnut and the leaf blister of the pear, both of which are very common in California.

The *Eriophyes vitis* is not a true insect, but a mite or acarid belonging to the class of Arachnida to which belong also spiders, scorpions, ticks, and our common red spider so destructive to fruit trees. These mites are extremely minute, and only a practiced eye can perceive them among the tangled mass of erineum on the leaf, by the aid of an ordinary hand magnifier, and then only with great difficulty.

Amount of Injury.—Erinose was formerly considered to be a very serious disease of the vine, owing to the fact that its effects were confused with those of the powdery mildew. It is only in very exceptional cases that it is, alone, capable of doing serious injury to the vine or its crop. When accompanying oidium or drought it may, however, perceptibly increase the damage due to these causes. When very abundant it may seriously interfere with the growth of young vines, but according to Mayet, never damages old vines, except by interfering slightly with the ripening of the canes, or at most causing an almost imperceptible diminution of crop. All varieties of vines are not equally attacked. According to Ravaz, certain American species such as Berlandieri, Mustang, Cinerea, Cordifolia, and Scuppernong are immune. All varieties of Vinifera are susceptible, but not equally. Of varieties cultivated in California, Sauvignon, Sirah, Marsanne, and Gamay Teinturier are said by Ravaz to be little subject to attack; while Aramon, Cinsaut, and Frontignan (Small Muscatel) are very susceptible. The worst cases so far observed in California have been on Flame Tokay and Mission, but it has been found also on other varieties, among them Zinfandel and Muscat.

Distribution in California.—The first specimens of erinose received by the Experiment Station were sent from Windsor, Sonoma County, in 1896. The next year affected leaves were received from Healdsburg and Dry Creek, in the same county. All these cases were upon Mission vines. Since then specimens of the disease have been received from nearly every grape-growing county of the State.

Methods of Treatment.—Since sulfuring the vines for the treatment of oidium has become general in France, there has been little trouble with erinose. The mite seems as sensitive to the fumes of sulfur as the red spider, and several sulfurings during the late spring and early summer are recommended for the control of the mite. The only vineyards which have been found badly affected in California are those in which little or no sulfuring has been done, or those where the growth of foliage has been so luxuriant as to prevent the evaporation of the sulfur by the sun. In the latter cases the vines are so strong that they practically receive no harm from the disease. Tests made on Tokay vines indicate that the erinose can be easily and readily controlled at any stage in California by sulfuring. In severe cases a winter treatment of the vine stumps is practiced in France. This treatment consists in pouring about one quart of boiling water over the stump. For very large stumps a somewhat greater amount of water is used, and for smaller vines a proportionate amount. This method is said to be very efficacious, and with the portable boiler constructed for the purpose two men can treat from fifteen hundred to two thousand vines per day. Cuttings taken from affected vines for the purpose of rooting or grafting may be thoroughly disinfected by placing them in hot water (122° F.) for ten minutes. If this is done carefully all the mites and their eggs will be destroyed without injury to the cuttings.

NEMATODE ROOT GALL.

(*Heterodera radicola* (Greef) Mull.)

Nematodes are not insects, nor are they very closely related to insects. They belong to the class of animals known as Vermes or true worms. The common earthworm is the best known example of the class, although it occupies a position in the group higher than that of the nematodes. There are a good many species of nematodes—some living in the ground, a good many are parasites on animals, and a few live parasitically on plants. Often in moist soil, rich in humus, such as vegetable gardens, there may be large numbers of very minute whitish transparent worms. These are nematodes, however, that do no noticeable injury to plants, and it is only the parasitic species, of which the subject of this account is an example, that are of any concern to growers of crops.

The species of nematode worm that attacks the grapevine in this State—according to Dr. Ernst Bessey of the Department of Agriculture, who is at present engaged in an investigation of this group—is *Heterodera radicola* (Greef) Mull. This species is widely distributed

over the world, and attacks a large variety of plants. In the Argentine Republic it is said to be the most destructive disease of the vine occurring in that country.* In the United States, outside of greenhouses, nematodes are chiefly injurious in the Southern States and in California.

This parasitic species is an exceedingly small wormlike creature about one seventy-fifth of an inch long, and of a transparent whitish color. It has a sharp slender organ on the head that enables it to make its way into the more tender portions of the roots, where it embeds itself in the tissues. Here it develops, and lays the eggs from which succeeding generations arise. These may scatter through the soil and attack other portions of the root. By means of this sharp lancelike organ they are able to draw nourishment from the roots. It is not so much this direct drain on the roots, however, that causes the damage as it is in the decay of the hypertrophied tissue due to the irritation caused by the work of the worms. They make conditions favorable for the attack of wood-rot fungi, which hasten the decay. The roots of vines infested with this worm show numerous swellings, somewhat like that due to phylloxera. The nodosities or swellings caused by phylloxera, however, are most conspicuous and are larger on the smaller roots, while those of nematodes are largest on the larger roots. The swellings are also of firmer consistency than those of phylloxera.

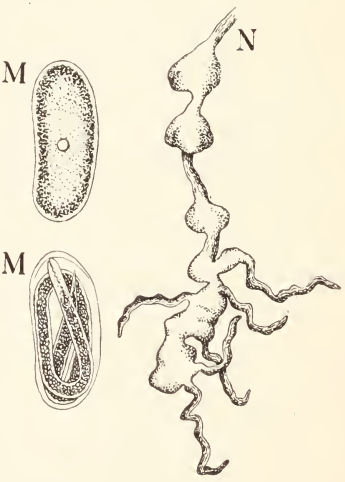

FIG. 24. N. Swellings on the roots of vine caused by the Nematode root gall. M, M. Eggs of the Nematodes found in these galls.

The general effect on the vine is not very different from that of the phylloxera. The distribution of the affected vines will, however, generally distinguish the two. Vineyards infested with phylloxera show the characteristic oil-spots, the interior vines being worst affected and gradually diminishing in injury toward the periphery of the affected spot. The amount of injury is said to vary with the soil conditions, but the authorities apparently are not agreed, some claiming less injury in light, sandy soil and others the reverse. Moisture is, no doubt, the most important factor in favoring their development. In California this pest seems to be most common on vines in the Fresno section, and, in general, this is a section of sandy soil.

Control.—No satisfactory remedy has yet been found for controlling parasitic nematodes. In greenhouses the usual procedure is to sterilize the soil, but this, obviously, is not applicable to a vineyard. However,

*Boletin del Ministerio de Agricultura, Buenos Ayres, Mayo de 1906.

if the soil is known to be infested, disinfection is sometimes practiced before planting out young vines. This is done by an application of carbon bisulfid to the soil. Trap plants have also been used, these being annuals that are pulled up before the nematodes escape. In time it may be found that resistant stock is the solution of the problem. In the bulletin already referred to it is stated that the Isabella is slightly resistant, while *Vitis riparia* has shown no nodules after the first year. This fact is interesting as a suggestion that both phylloxera and nematodes may be controlled by the same resistant.

KEY FOR DETERMINING THE INSECT INJURIES TO THE VINE DESCRIBED IN THIS BULLETIN.

Injury to the Leaves.

No part of the leaf eaten away, but having pale spots, or being entirely pale yellow, or dried up, those about the crown of the vine, particularly the lower ones, worst affected. *Vine hopper*, page 111.

Leaves with irregular holes eaten out. *Flea beetles*, page 128; *Grasshoppers*, page 122; or *Leaf chafers*, page 132.

Leaves with regular chain-like slits eaten away. *Root beetles*, page 116.

Leaves rolled up from one side. *Leaf rollers*, page 129.

Leaves entirely devoured. *Army worms*, page 124; *Grasshoppers*, page 122; *Hawk moth larvæ*, page 119.

Leaves with swellings on upper surface, and grayish white to dark, brown felt covering on corresponding depressions on under side. *Erinose*, page 134.

Injury to Petioles and Pedicels.

Narrow strips of uniform size eaten away. *Root beetle*, page 116.

Injury to the Berry.

Narrow strips about one fourth of an inch long gouged out. *Root beetle*, page 116.

Clusters cut off and dropped to ground. *Army worm*, page 124.

Injury to the Roots.

Long strips of the bark eaten away. *Root beetle*, page 116.

The smaller rootlets only eaten off. *Wire worm*, page 133.

Nodosities or swellings, largest on smaller roots, often at extreme tip, decay of hypertrophied tissue. *Phylloxera*, page 99.

Nodosities or swellings largest on larger roots, two or three times the diameter of those caused by phylloxera, and of firmer consistency, none at extreme tip. *Nematodes*, page 136.

Injury to the Whole Vine.

These are the same as under root injury, since injury to the roots affects the vine as a whole.

Vines whose canes are checked in growth or completely stunted, and if leaves have chain-like strips eaten out. *Root worm*, page 116.

Vines in circular spots in vineyard showing stunted growth, those in center of spot worst affected and gradually diminishing outward. *Phylloxera*, page 99.

Vines with symptoms similar to phylloxera, but not in well-defined circular spots, nor with interior ones worst affected. *Nematodes*, page 136.

HOW TO SEND SPECIMENS.

Insect specimens should be inclosed in a wooden, tin or strong pasteboard box. No provision need be made for air. Accompany specimens with samples of their work. If roots or leaves, wrap in moist newspaper and inclose in tight box to prevent drying. If phylloxera is suspected, place pieces of roots in a firm box that is absolutely tight; or otherwise thoroughly seal, to prevent any possibility of escape in the mails.

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1896. Report of the Viticultural Work during the seasons 1887-93, with data regarding the Vintages of 1894-95.
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1898. Partial Report of Work of Agricultural Experiment Station for the years 1895-96 and 1896-97.
1900. Report of the Agricultural Experiment Station for the year 1897-98.
1902. Report of the Agricultural Experiment Station for 1898-1901.
1903. Report of the Agricultural Experiment Station for 1901-1903.
1904. Twenty-second Report of the Agricultural Experiment Station for 1903-1904.

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185. Report of Progress in Cereal Investigations.
186. The Oidium of the Vine.
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188. Lining of Ditches and Reservoirs to Prevent Seepage and Losses.
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190. The Brown Rot of the Lemon.
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